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Chesapeake Bay blue crabs and consumption related illness

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Chesapeake Bay Blue Crabs and Consumption Related Illness

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Abstract

Currently, 72.2% of the Chesapeake Bay is impaired due to pollutants that impaired water quality. Some common pollutants in the Bay that are also toxic if consumed are: polychlorinated biphenyls (PCBs), mercury, and lead. Pollutants tend to settle on the Bay floor and become accumulate in the sediment. Most shellfish and small finfish live near or on the Bay floor and are may be exposed to high levels of pollutants. Therefore, bioaccumulation and biomagnification of pollutants can occur in shellfish and finfish tissues. These pollutants may cause a risk to human health by either increasing the risk of developing cancer or through systemic toxicity. Blue crabs were collected from James Madison University's property in Bluff Point, Virginia and sent to REIC Lab in Verona, Virginia to be analyzed for PCBs, mercury, and lead. Data from Virginia's Department of Environmental Quality's Fish Tissue Monitoring Program was also analyzed. Using the concentrations of lead, mercury, and PCBs in the blue crab tissue, a risk assessment was done to determine the human health risks of consuming blue crabs from the Chesapeake Bay. The results show that consumption of blue crabs from the Chesapeake Bay can cause an increased risk of developing cancer due to PCBs and a risk of systemic toxicity from lead.

Acknowledgments

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Glossary of Acronyms

- ADD - average daily dose
- ATSDR - Agency of Toxic Substances and Disease Registry
- CDI - chronic daily intake
- EPA - Environmental Protection Agency
- HQ - hazard quotient
- MDL - method detection limit
- NOEL - no observable effect level
- PCBs - poly chlorinated benzene
- PF - potency factor
- REIC - Research Environmental Industrial Consulting
- RfD - reference dose
- SQG - sediment quality guidelines
- TOC - total organic carbon
- VaDEQ - Virginia Department of Environmental Quality
- VDH - Virginia Department of Health

1. Introduction

Within a watershed, everything flows downstream. A single grain of sand has the potential to travel thousands of miles before finally accumulating on the ocean floor. Bacteria, sediment, paper, plastic, chemicals, metals, and fecal matter follow the flow of water downstream. As a result, contamination in the Chesapeake Bay's watershed will travel into the Bay.

The Chesapeake Bay is an estuary with 200 miles of coast and watershed of approximately 62,000 square miles; it has become a focal point for accumulation of water contaminants.[1] There are approximately 15 trillion gallons of water in addition to hundreds of species of finfish and shellfish living in the Chesapeake.[2] Contaminants arrive from the all of it's tributaries, particularly the Susquehanna, Potomac, Rappahannock, York, and James Rivers and directly affect the health of marine life in the Bay.

Currently, nitrogen pollution is the most prevalent source of contamination.[3] Poor water clarity, low dissolved oxygen content, and toxins such as PCBs and mercury remain rampant in the Bay, resulting in a poor water health.[1]

1.1 How Toxins Affect Marine Life

The Chesapeake Bay serves as a recreational water body and a valuable fishery. Commercial fishermen harvest about 500 million pounds of seafood from the Bay annually.[2] The intricate coastline provides sanctuary for the Bay's inhabitants, including the blue crab, oysters, clams, and fish. When pollutants arrive in the Bay, they can settle in the crevices of the coastline. Once the Bay has been reached, the contaminant is more likely to settle in the sediment than to continue into the ocean. This creates an issue for marine life, especially those which dwell upon the Bay floor. The Chesapeake Bay Foundation, a non-profit organization that works to restore

the Bay, gives different water health issues a grade in their biannual *State of the Bay Report*. In 2014, water clarity, dissolved oxygen, toxins, nitrogen, and phosphorus all received low grades (Table 1).

Table 1. 2014 State of the Chesapeake Bay report card score. The State of the Bay Report is provided by the Chesapeake Bay Foundation.

	Water Clarity	Dissolved Oxygen	Toxins	Nitrogen	Phosphorus
2014	F	C	D	F	D -

Once pollutants are in the bay, they may bioaccumulate in marine life. Bioaccumulation is the accumulation of a substance in an organism. Bioaccumulation may be in the form of bioconcentration or biomagnification. Bioconcentration is the accumulation of a chemical in an organism directly from its surroundings. An example of this is marine life accumulating contaminants from living in polluted waters. Biomagnificaton refers to the accumulation of a chemical through a food-chain.

1.2 Discussion of Toxic Pollutants

The primary pollutants in the Chesapeake Bay responsible for harsh effects on human health are poly-chlorinated biphenyls (PCBs), mercury, and lead.[3] Before the manufacturing of PCBs was banned in 1979, PCBs were widely used as dielectric and coolant fluids in transformers and capacitors and are released into the environment when equipment containing PCBs fails.[4] Chemically inert, non-flammable, and heat-resistant, PCBs have favorable characteristics for use as a coolant and insulation fluid. However, the chemical compound is also lipophilic, persistent, easily accumulated, and forms colorless, odorless crystals which do not readily degrade due to

low water solubility and high mixture viscosity which increases with higher levels of chlorination.

Known animal carcinogens, PCBs are considered a highly probable human carcinogen. The chemicals, present in the environment as a mixture, has a biphenyl ring structure with 1 to 10 chlorines, which forms 209 congeners (Figure 1). The shape of the PCB molecule depends heavily on the location of the chlorine atoms. As the number of chlorine atoms present increases, so does the toxicity of the molecule. Molecules lacking the chlorine atom in the ortho position are known as coplanar PCBs. Because the molecular structure of coplanar PCBs is flat, it is more mobile than non-coplanar PCBs and therefore more toxic.

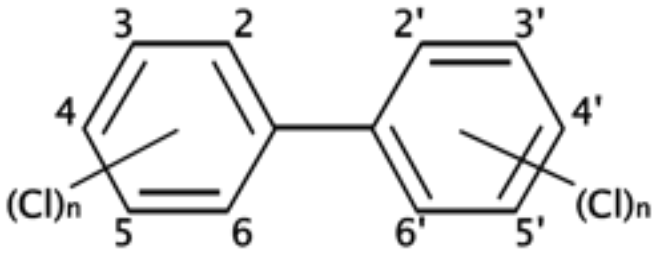

Figure 1. General molecular structure of poly-chlorinated biphenyls. Chlorines may attach to any of the tertiary carbons. The greater number of chlorines, the more toxic the chemical.

Mercury is released through fuel and waste burning, mining and ore processing, chemical production, and agriculture.[3] When released into a water supply, naturally-occurring bacteria transform the mercury into methyl mercury.[5] Methyl mercury then accumulates in the tissues of fish and the concentration magnifies as the food chain progresses.[9] Mercury is a neurotoxin and can cause blindness, deafness, and nerve damage depending on the amount consumed.[5] According to the Agency for Toxic Substances and Disease Registry (ATSDR), the human nervous system is very sensitive to all forms of mercury.

A common way humans are exposed to mercury is through consumption of fish, or shellfish, that have accumulated methyl-mercury.[6] Long-term exposure to mercury may cause negative effects on brain functioning, the kidneys, and developing fetuses.[6] Mercury is also considered a possible human carcinogen. There is evidence of mercury as a carcinogen in animal studies, but not enough evidence in humans to declare it a probable human carcinogen.[6] According to the ATSDR, the Food and Drug Administration has set a maximum permissible level of 1 part of methyl-mercury in a million parts of seafood (1 ppm).[7]

Lead may enter the environment from a variety of sources; these include: paint, gasoline, older plumbing where lead or lead solder in copper pipes was used, and a variety side-products from different manufacturing processes. According to the Agency for Toxic Substances and Disease Registry, the main target for lead toxicity is the nervous system. Long-term exposure to lead can cause decreased functioning of the nervous system.[8] Furthermore, lead can affect the cardiovascular, developmental, reproductive, gastrointestinal, hematological, musculoskeletal, neurological, ocular, and renal systems.[8] Lead is also reasonably anticipated to be a human carcinogen.[8] Consuming food or drinking water that contains lead is one of the most common ways humans come into contact with lead.[8] The Center for Disease Control considers a child's blood lead levels to be of concern if they are equal to or higher than 5 micrograms per deciliter.[8] Lead levels in any amount in the blood are considered a contribution to neurological problems.

1.3 Seafood Species of Interests

Throughout the Chesapeake Bay watershed, seafood is culturally significant food. It comprises a major portion of the diet of people native to the region. Seafood is an excellent source of protein and a range of nutrients, most notably is omega-3 fatty acids.[9] Currently, it is recommended to eat 8 ounces, or two meals, of seafood a week.[9] According to the United States Department of Agriculture, the health benefits of consuming seafood outweigh the risks associated with it.[9]

The blue crab, *Callinectes sapidus,* is an iconic species of the Chesapeake Bay. It is one of the fourteen swimming crab species in the genus Callinectes.[10] For the past few centuries, "the harvest and consumption of blue crabs have supported coastal communities and connected people to the Chesapeake Bay. The Chesapeake Bay blue crab is widely considered one of the best-tasting crabs in the world."[10]

While the blue crab has been one of the most plentiful species in the Bay, its habitat extends beyond the Bay to the surrounding estuaries and coastal habitats of the Western Atlantic, Gulf of Mexico, and the Caribbean.[10] While the blue crab can inhabit large geographical range, the Bay has been a particularly good habitat for blue crabs due to its favorable salinity, temperature, and dissolved oxygen levels, varied bottom structure, plentiful nutrients from submerged aquatic vegetation, strong tides and water structure.[10]

Blue crabs are benthic creatures, opportunistic predators and scavengers.[10] They will prey on bivalves, crustacea, and fish.[10] The main reason they are such efficient predators is their sideways swimming capabilities. Furthermore, "their shallow compressed body with tapered ends is designed for speed."[10] They also have excellent eyesight. The blue crab is a solitary animal, only coming together for mating. In the Chesapeake Bay, male blue crabs occupy parts of the upper

bay and upper reaches of the tributaries, where salinity levels are lower. Females prefer the lower bay and lower reaches of the tributaries, where there are higher salinity levels.[10]

1.4 James Madison University's Property at Bluff Point

James Madison University owns a property in Bluff Point, Virginia, which is adjacent to the Chesapeake Bay (Figure 2). Bluff Point is on the northern neck of Virginia just outside of Kilmarnock, Va. The land encompasses part of the shore of the Chesapeake Bay. The property is mostly natural landscape with rotting timber and overgrown grass lining the shore (Figure 3).

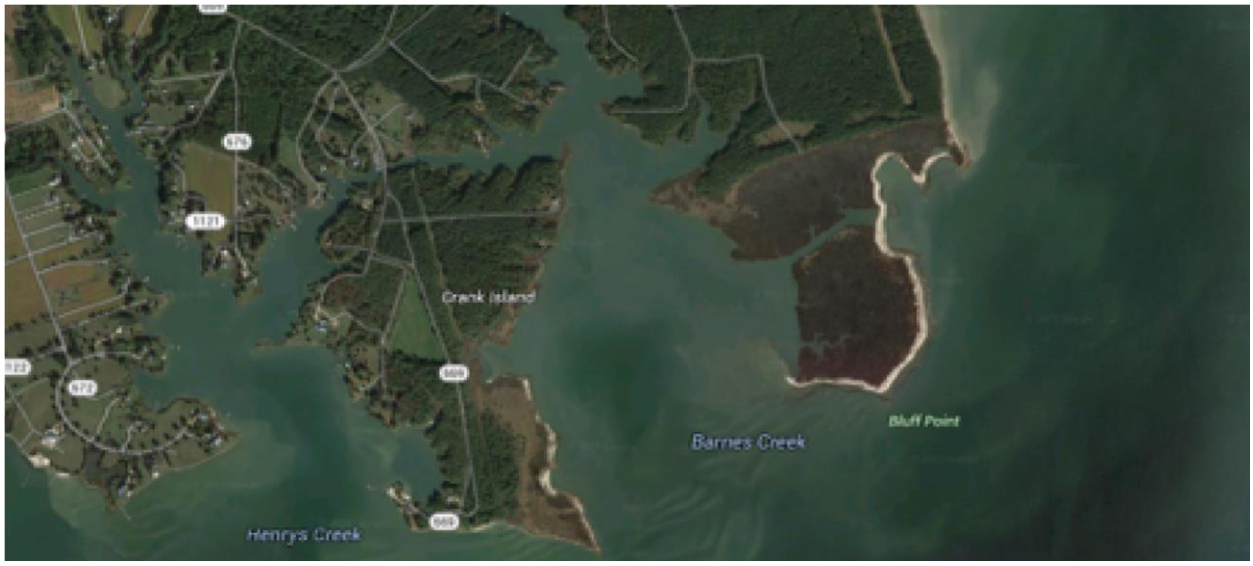

Figure 2. Map of James Madison University's property in Bluff Point, Virginia. Blue crabs were collected along the Bluff Point shoreline, which may be seen in the map.

Figure 3. Shoreline at Bluff Point property. As the shore erodes, trees fall and line the shore. This property was used to collect Blue Crab specimens.

A sediment quality analysis was conducted on August 28, 2008 near the Bluff Point blue crab collection site.[11] The sediment sample was collected and examined for parameters indicating contamination. These parameters include total organic carbon (TOC), cyanide, metals of concern, and semi-volatile organics (including PCBs). [11] At the time of measurement, in-situ data collection methods were applied for temperature, salinity, and pH. [11] Grain size and the sediment's ability to retain compounds were taken into consideration. [11]

In the resulting analysis, TOC was 15,300 mg/kg (1.53%).[11] This concentration is lower than the upper boundary (3.0%) suspected of causing reduction in benthic organism abundance and biomass.[11] The majority of pollutants were found to be below the method detection limit (MDL). [11] However, some metals were measured above the MDL. All measurements except GNV/2008/071653A/ 11/3/2009 2-12 arsenic were below accepted sediment quality guidelines (SQGs). Mercury and lead were detected above the MDL while PCBs were not detected within

the sediment sample.[11] Average mercury in the sample resulted in 23.75 mg/kg, above the MDL of 2.8 mg/kg. Average lead concentration in the sediment was 8.98 mg/kg, above the MDL of 0.5 mg/kg. [11]

1.5 U.S. EPA Seafood Consumption Guidelines

EPA guidelines for shellfish consumption apply specifically to woman who might become pregnant, women who are pregnant, nursing mothers, and young children.[12] These demographics are most susceptible to contaminants found in seafood. The guidelines highlighted from the U.S. EPA warn to avoid shark, swordfish, king mackerel, or tilefish due to the potential of high levels of mercury.[12] They also recommend eating fish or shellfish that are lower in mercury such as shrimp, canned light tuna, salmon, pollock, and catfish.[12] Consumption of albacore tuna should be reduced[12]. The EPA also advises consumers of shellfish and finfish to check local advisories about the safety of fish caught by family and friends, or if no advice is available, restrict consumption to one meal a week of finfish or shellfish.[12]

1.6 Fish Tissue Program Monitoring

The data from all locations within the Chesapeake Bay Small Coastal Drainage was analyzed. Virginia's Department of Environmental Quality had a screening level of 0.03 ppm for mercury.[13] There is no screening level for lead because a safe concentration of lead has not been determined.[14] Currently, the Va DEQ's screening level for PCBs is 54 ppb, but a new screening level of 20 ppb has been proposed.[13] For PCBs, the Virginia Department of Health has set a lower level of concern of a concentration of 50 ppb and an upper level of concern of 500 ppb.[13]

1.7 Quincy Bay Case Study

Quincy Bay is located in Massachusetts, just south of Boston and is very popular with recreational fishermen.[15] A study by the Environmental Protection Agency was done to quantify the types and concentrations of pollutants and the extent sludge present in Quincy Bay.[15] The study also included an evaluation of public health risks associated with consuming seafood from Quincy Bay.[15] Lobsters were one of the three species tested for polyaromatic hydrocarbons, polychlorinated biphenys, and a variety of other compounds.[15] Both lobster tissue and hepatopancreas was tested. Hepatopancreas showed, on average, a greater concentration of various contaminants than the tissue.[15] The hepatopancreas is an organ that is a part of the digestive tract in fish and shellfish. Due to the results of the Quincy Bay study and because lobsters and blue crabs are closely related species, it was decided to test the hepatopacreas of the blue crab along with the muscular tissue.

2. Materials for Capturing Blue Crabs and Preparing Samples for Analysis

- Two coolers
- Two fishing nets
- Raw chicken legs
- Fish as bait
- Hooks
- Sturdy string
- One small crab trap
- Two large crab traps
- 4 glass jars
- Scalpels
- Wooden Hammers
- Paper Plates for organization
- One pot
- 10 blue crabs
- Virginia State Fishing License

3. Field Methodology

The goal was to collect ten male crabs that were Virginia's Department of Game and Inland Fisheries regulation size of five inches from tip to tip. A sample size of ten was advised because of it was large enough to be statically significant, but small enough that it was feasible to collect the samples in a single day.

James Madison University's property in Bluff Point, Virginia has a pier over Barnes Creek, which empties into the Chesapeake Bay. One small crab trap and two large crab traps were baited with fish and lowered off of this pier. Next, five raw chicken legs were tied to strings and lowered off of the pier. These chicken legs were spaced around the entire deck, especially in areas that were shaded. Using the fish net, two blue crabs that drifted near the bait were captured. Since capturing crabs by hand was not very efficient, 17 crabs were purchased from local waterman Mike Croxton. Mr. Croxton assured that the crabs he caught were from the Chesapeake Bay.

Figure 4. Blue Crab specimens collected at Bluff Point property, crabs were contained within a cooler until they could be processed.

The crabs were kept on ice inside of a cooler, within 3 hours those still living were steamed in a large pot (Figure 4). Steaming is the method traditionally used for cooking blue crabs. After cooking, the ten crabs with the most appendages attached were labeled 1-10 and picked for their meat. Before the crabs were picked, paper plates were labeled from 1-10, and coded according to the type of tissue collected (Figure 5). Due to the liquid nature of the hepatopancreas, it was placed on the paper plate in the corresponding crab's outer shell. The hepatopancreas was contained in the crab's shell until the measurement of mass.

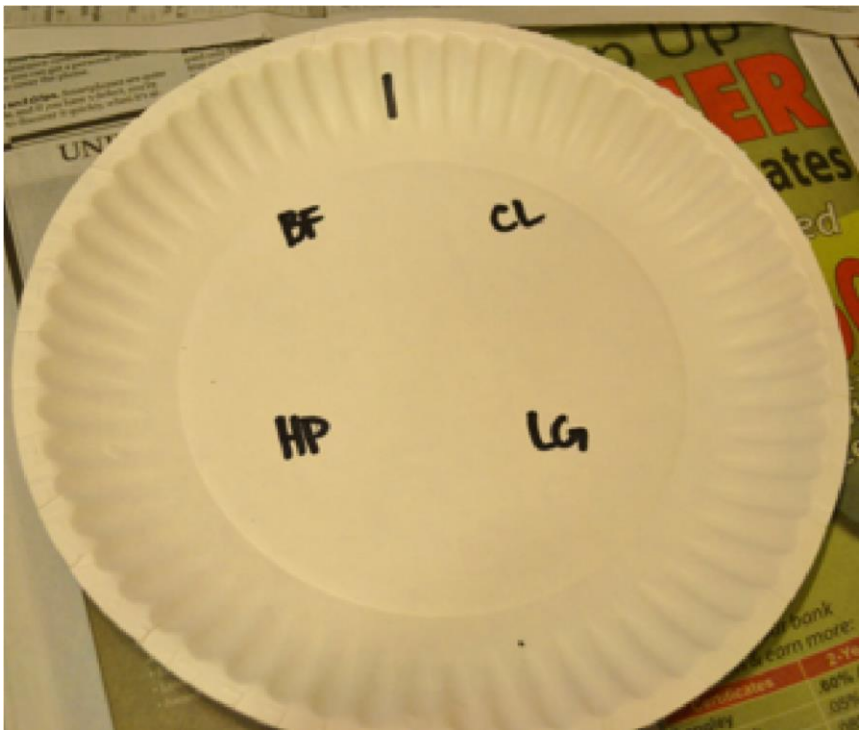

Figure 5. Paper plate layout used for separation of meat. BF was the backfin tissue, CL was claw tissue, HP was hepatopancreas, LG was leg.

Figure 6. A specimen with the outer shell removed. Various tissues and organs can be seen. The outer shell was removed from each blue crab specimen in order to reach the hepatopancreas and backfin tissue.

On each paper plate, the meat was organized into four different piles corresponding to the labeling on the plate: backfin, claw, leg, and hepatopancreas (Figure 7). Each amount of tissue was measured using a kitchen scale accurate to 0.1 gram. The amount collected from each tissue type were: 3 grams of backfin, 3 grams of claw, 2 grams of leg, and 1 gram of hepatopancreas. To create composite samples, each of the different tissue types were placed into one of the four corresponding jars provided by the lab and preserved on ice in a cooler until they could be delivered to the lab for analysis. The 16 oz. jars were made of glass with a screw-cap closure system. Each jar was labeled with the date of sample collection, the time they were composited in the jar, the type of tissue, and the location where they were sampled.

Figure 7. Crab separated on paper plate into the following components: backfin tissue, claw tissue, leg tissue, and hepatopancreas tissue.

4. Laboratory Analysis by Research Environmental Industrial Consultants (REIC)

The Research Environmental Industrial Consultant (REIC) Lab in Verona, Virginia was used to analyze samples of the blue crab muscular tissue for PCBs, mercury, and lead.

4.1 Analytical Measurement Method for Polychlorinated Biphenyls

The analytical measurement method for PCBs followed the EPA method E8082. A measured volume or weight of crab tissue sample was extracted using a designated matrixspecific sample extraction technique. Solid tissue samples are extracted with hexane-acetone, or methylene chloride-acetone, using the Soxhlet method, the automated Soxhlet method, the pressurized fluid extraction method, the microwave extraction method, the ultrasonic extraction method, the supercritical fluid extraction method, or other appropriate technique or solvents.

Tissue samples may be extracted using the supercritical fluid extraction method, or other appropriate technique. The extraction techniques for other solid matrices may be appropriate for tissue samples. PCB analysis may be exposed to a successive sulfuric acid/potassium permanganate cleanup. This cleanup technique removes many single component organochlorine or organophosphorus pesticides. For this reason, this method does not apply to the analysis of those compounds.

After cleanup, the extracted sample is analyzed through the injection of an aliquot into a gas chromatograph equipped with either a narrow- or wide-bore fused-silica capillary column. Another way to analyze the sample is with either an electron capture detector or an electrolytic conductivity detector. The chromatographic data may be used to analyze the presence of any of the seven Aroclors, selected individual PCB congeners, or total PCBs.

4.2 Analytical Measurement Method for Lead

The analytical measurement method for lead followed the EPA method E6020A. Before analysis, samples are solubilized or digested using sample preparation methods. This method defines the multi-elemental determination of analytes by ICP-MS in environmental samples. The analysis method measures ions produced by a radio-frequency inductively coupled plasma. Analyte species originating in a liquid are nebulized and the resulting aerosol is transported by argon gas into the plasma torch. Ions formed from high temperatures are placed in the plasma gas and extracted through a differentially pumped vacuum interface and divided on the basis of their mass-to-charge ratio by a mass spectrometer. The ions transmitted through the mass spectrometer are measured by a channel electron multiplier or Faraday detector. The ion information is managed by the instrument's data handling system. Interferences must be assessed and valid corrections applied or the data qualified to indicate problems. Interference correction must include compensation for background ions contributed by the plasma gas, reagents, and constituents of the sample matrix.

4.3 Analytical Measurement Method for Mercury

The analytical measurement method for mercury followed the EPA method SW7471B. Before analysis, the crab tissue samples are prepared according to lab procedure. The method used to detect mercury applies cold-vapor atomic absorption and is based on the absorption of radiation at the 253.7-nm wavelength by mercury vapor. The mercury is reduced to the elemental state and aerated from solution in a closed system. The mercury vapor passes through a cell positioned in the light path of an atomic absorption spectrophotometer. Absorbance is measured as a

function of mercury concentration. The typical instrument detection limit for this method is 0.0002 mg/L.

5. Risk Assessment Methodology

A risk assessment is conducted to quantify if contamination at a specific site is at a level that could cause harm. A risk assessment can be conducted to quantify the risk contamination poses to either the local ecosystem or to human health. An ecological risk assessment considers the risk a contaminant poses to all organisms, while a human health risk assessment only considers the risk a contaminant poses to people.[16]

In this report, the human health risk assessments were conducted in order to quantify the risk of consuming seafood from the Chesapeake Bay. The first step of the risk assessment was to interpret site data and determine what does pose a risk and what does not pose a risk. This was achieved by analyzing the concentration of PCBs, mercury, and lead and comparing these concentrations to screening levels proposed by the Virginia Department of Health and the Virginia Department of Environmental Quality. A screening level is a level of concentration that identifies that a risk assessment should be conducted for that contaminant.[16] Screening levels are generally based on generic, conservative risk assessments and are only intended to determine what contamination needs further investigation.[16] If a concentration of a contaminant is greater than the screening level, the contaminant is considered of concern and a risk assessment is conducted.

A toxic contaminant may either be carcinogenic, meaning it can cause cancer, or non-carcinogenic. Whether a toxin is carcinogenic or not is determined typically by animal testing and/or by epidemiological studies of exposed humans.[16] If a toxin is carcinogenic, it is assumed to cause mutations within the human genome that initiate cancer. Since only one such mutation is needed to initiate cancer, there is no safe limit of exposure to carcinogens. The EPA and VaDEQ have therefore set arbitrary standards of what they believe is an acceptable level of risk

of developing cancer. These standards are used to determine if remediation of a carcinogenic contamination is needed.

If a contaminant is non-carcinogenic, the toxicity is quantified by animal testing and a dose-response curve is developed. A dose-response curve shows a threshold concentration limit, where a certain level of exposure causes no observable effect.[16] As the exposure increases, the response increases until it reaches an asymptote, where a greater increase in exposure no longer causes an increase in response.[16] The dosage can then be quantified and the no observable effect level determined (NOEL).[16]

According to Dr. Alex Barron, Virginia's Department of Environmental Quality considers mercury and lead to be neurotoxins. These toxins primarily affecting the central nervous system, especially the developing nervous system in the fetus and in young children. Therefore, mercury and lead will undergo a non-carcinogenic risk assessment, while PCBs will undergo a carcinogenic risk assessment.

The EPA has set a variety of standards to be used when doing risk assessments. These include: the average value for consumers body weight is 70 kg, for children it is 15 kg, and a consumption rate of 17.5 grams/day of fish consumed per day or 14.08 pounds/year.[17] This standard consumption rate is based upon the 90th percentile value for consumption rates of freshwater and estuarine fish shellfish as reported in the USDA's CSFII Survey for 1994-1996.[14]

5.1 Non Carcinogenic Risk Assessment

A reference dose (mg of contaminant/kg of body weight/day) is the dose of the toxic substance that can be ingested systemically and present no significant risk. A reference dose is extrapolated from the no observable effect level of the dose-response curve of the given contami-

nant.[16] An uncertainty factor is added to the no observable effect level in an effort for the reference dose to represent a safe level for human exposure.[16]

The mercury that bioaccumulates in fish is in the form of methyl mercury. According to the EPA's IRIS database, methyl mercury has a reference dose of 0.0001 mg/kg body weigh/day. The EPA does not have a recommended reference dose for lead. This means that the EPA could not determine a level of exposure that does not cause adverse effects, therefore any lead detected in fish is a concern.

To evaluate the risk of systemic toxicity, a hazard quotient is used. The following equation is used to determine the hazard quotient (HQ):

$$\text{Hazard Quotient} = \frac{\text{Average Daily Dose During Exposure Period}}{\text{Reference Dose}} \text{ (mg/kg-day)}$$

If the hazard quotient is <1, there is no significant risk of systemic toxicity.[16] Using the conditions for standard exposure and toxicological values, fish/shellfish values at or below a concentration of 0.40 mg/kg methyl mercury in edible muscle tissue would pose no significant risk to human health. The VaDEQ recognizes that in addition to eating locally caught fish and crabs, people also eat the commercially caught fish that contains trace amounts of methyl mercury.[14] The EPA estimates that the average level of exposure from commercial fish is 0.1 mg/kg/day, therefore 0.3 mg/kg methyl mercury in fish or shellfish is acceptable.[14]

5.2 Carcinogenic Risk Assessment

PCBs are classified as a carcinogen and therefore have a different risk assessment. The EPA has identified a risk of 1 in 1,000,000 as an acceptable risk for a carcinogen, however Virginia's Department of Environmental Quality uses a risk of 1 in 100,000 as an acceptable level of risk.

The following formulas are used when conducting a risk assessment for a carcinogen:

Incremental Li

$$\text{Chronic Daily Intake (mg/kg-day)} = \frac{\text{Average Daily Dose (mg/day)}}{\text{Body Weight (kg)}}$$

The potency factor, also known as the oral slope factor, is particular for each carcinogen and is the slope of a dose response curve where the curve is assumed to be linear.[17] The incremental lifetime risk is the portion of a lifetime spent exposed to a carcinogen. According to the EPA's IRIS database, the potency factor for PCBs is 2.0 mg/kg/day. Using the potency factor, the allowable concentration of PCBs in fish/shellfish tissue can be calculated.

6. Results and Analysis

For the purpose of the risk assessment, data was analyzed from two separate sources. First, the results from blue crab samples collected at Bluff Point were used. The second set of results analyzed was a subset of data collected by the Virginia Depart of Environmental Quality for the Fish Tissue Monitoring Program. This data came from a variety of locales within the Chesapeake Bay (Table 1). In 2008, the Fish Tissue Monitoring Program analyzed blue crabs data from five locales within the Chesapeake Bay Small Coastal Drainage (Table 2). Within each of these locales, crabs were analyzed from 3-6 sampling sites. At each sample site, 10 - 16 blue crabs were collected.

Table 2. Sampling locales for the Tissue Monitoring Program that were within the Chesapeake Bay Small Coastal Drainage where blue crabs, oysters, and striped bass were collected. Each locale had 3-6 sampling sites within it. The number of blue crabs represents the total amount of specimen that were collected from that locale.

Locale	# of Blue Crabs
Lower Chesapeake Bay	71
Lower Peninsula Between James & York River	106
Middle Peninsula Between York River & Rappahannock River	79
Northern Neck Peninsula Between Rappahannock & Potomac River	66
Chesapeake Bay Eastern Shore	57

Analyzing the data involved determining if there were any contaminants of concern present in any of the seafood tissue samples and if contamination was of concern, a risk assessment was conducted. Any data reported that was below the method detection limit of the analysis was treated as one half of the method detection limit; this treatment ensures that the concentration of a contaminant is closer to the true value than other treatments (Table 3). This method of treated data below detection level ensures the closest approximation to the true value. The other com-

mon methods for treating data below the detection limit is to treat the data as equal to the detection limit, which yields an overestimation, or as 0, which yields a underestimation.

Table 3. Detection limits for mercury and lead analysis done by Virginia's Department of Environmental Quality's Fish Tissue Program. The detection limit is the lowest concentration of contaminant that was able to be detected by the analysis. Data below detection limit was treated as one half of the detection limit.

Toxins	Detection Limit (ppm)	Treatment (ppm)
Lead	0.1	0.05
Mercury	0.01	0.005

Screening levels set by Virginia's Department of Environmental Quality and by Virginia's Department of Health were used to help determine if a contaminant was of concern. Currently, the DEQ's screening level for PCBs is 54 ppb, however a screening level of 20 ppb has been proposed. Virginia's Department of Health has set the screening level for the lower level of concern at 50 ppb and the upper level of concern at 500 ppb (Table 4). Since the EPA's newly proposed screening level of 20 ppb is the most conservative of the screening levels, this was the screening level used to determine if the concentration of PCBs was a concern. The DEQ's screening level for mercury is currently set at 0.3 ppm with no proposed change. Virginia's Department of Health's level of concern for mercury is currently 0.5 ppm (Table 4). Since the DEQ's screening level of 0.3 ppm was the most conservative of these screening levels, it was the one used to determine if the concentration of mercury was a concern (Table 4).

Currently, Virginia's Department of Health and the Department of Environmental Quality have no screening level for lead. This is because a level of lead that does not cause adverse health effects has not been determined, therefore any level of lead is a concern. Since any lead detected poses a concern to human health, treating lead as one half of the method detection limit would cause the concentration lead to be of concern. Therefore, if after treating the results as

one half of the method detection limit, the average concentration was equal to or less than the method detection limit, it was assumed lead was not of concern.

Table 4. Screening Levels proposed by Virginia's Department of Health and by the Department of Environmental Quality for concentration of mercury, lead, and PCBs in fish and shellfish.

Toxins	DEQ Screening Level		VDH Screening Level	
	Current Screening Level	Newly Proposed	Lower Level	Upper Level
Lead	N/A	N/A	N/A	
Mercury	0.3 ppm	0.3 ppm	0.3 ppm	0.5 ppm
PCBs	54 ppb	20 ppb	50 ppb	500 ppb

6.1 Bluff Point

Blue crab backfin and hepatopancreas tissue samples were sent to the REIC lab for PCBs, mercury, and lead analysis. No mercury or PCBs were detected in the backfin tissue (Table 5). Lead was detected at a concentration of 0.138 mg of lead/kg of backfin tissue (Table 5). In the hepatopancreas sample, lead, mercury, and PCBs were not detected (Table 5).

Table 5. Comparison of concentration of various toxins in blue crab backfin and hepatopancreas tissue. A composite sample of 10 blue crabs was analyzed for lead, mercury, and PCBs by REIC lab in Verona, Virginia. The method detection limit (MDL) represents the lowest concentration that could be detected. Each different Acolor is a different PCB congener.

Toxins	Concentration (mg/kg) in Backfin	Concentration (mg/kg) in Hepatopancreas	MDL (mg/kg)
Lead	0.138	Not Detected	0.025
Mercury	Not Detected	Not Detected	0.020
PCB - Arcolor 1016	Not Detected	Not Detected	0.0115
PCB - Arcolor 1221	Not Detected	Not Detected	0.0136
PCB - Arcolor 1232	Not Detected	Not Detected	0.00671
PCB - Arcolor 1242	Not Detected	Not Detected	0.0144
PCB - Arcolor 1248	Not Detected	Not Detected	0.00415
PCB - Arcolor 1254	Not Detected	Not Detected	0.00395
PCB - Arcolor 1260	Not Detected	Not Detected	0.00330

This results correlate in part with the sediment quality report conducted in August of 2008 (see section 2.4.1). In the sediment quality report, concentration of mercury in the sample was on average 23.75 mg/kg and lead in the sample was found to be 8.98 mg/kg. PCBs were not detected in either the sediment sample or in the blue crab sample. While mercury was detected in the sediment sample, it was not found in the blue crab sample (Table 6). However, lead was detected both in blue crabs and in the sediment sample (Table 6). This indicates that lead from the sediment has bioconcentrated in blue crabs. Since blue crabs are benthic organisms, this was expected. Unlike the results from the study done at Quincy Bay, Massachusetts, the hepatopancreas did not show a greater concentration of contaminants.

Table 6. Comparison of concentration of various toxins in blue crab backfin tissue and of concentrations of toxins found in the sediment of the Bluff Point property. A composite sample of 10 blue crabs was analyzed for lead, mercury, and PCBs by REIC lab in Verona, Virginia. A Sediment Quality Report was prepared for the Bluff Point site in August, 2008. All concentration (mg/kg) represent the average of the respective sample

Toxins	Concentration in Backfin (mg/kg)	Concentration in Sediment (mg/kg)
Lead	0.138	8.98
Mercury	Not Detected	23.75
PCBs	Not Detected	Not Detected

Since mercury and PCBs were not detected, it must be assumed that they do not pose a risk to human health through consumption of blue crabs from Bluff Point. The Environmental Protection Agency has not been able to determine a minimal concentration of lead that does not pose a concern to human health, therefore any concentration of lead puts human health at risk. A human health risk assessment was conducted to quantify this risk (section 7.1).

6.2 Fish Tissue Program Monitoring

The data from Virginia's Department of Environmental Quality Fish Tissue Monitoring Program was also analyzed. The data from any location within the Chesapeake Bay Small Coastal Drainage was analyzed. Any value below the detection limit was treated as half of the detection limit. The concentration of PCBs in the blue crab tissue ranged from 2.66 - 25.94 ppb with an average of 13.23 ppb. The average concentration of PCBs is less than the EPA's newly purposed screening level of 20 ppb. However, two of the five locations did have concentrations of PCBs in tissue above the EPA's newly proposed screening level of 20 ppm (Table 7).

The concentration of mercury in the blue crab tissue ranged from 0.023 - 0.071 ppm with an average of 0.04 ppm. Therefore, the average concentration of mercury in blue crab tissue is higher than the screening level of 0.03 ppm.

The concentration of lead in the blue crab tissue ranged from 0.05 - 0.075 ppm with an average of 0.06 ppm. Four of the five locations had lead concentrations below the detection level of 0.01 ppm, these measurements were treated as 0.05 ppm. At four of the five sampling locales, all lead detected was below the detection limit. However, at Tabb Creek, which is within the Lower Peninsula between James and York River sampling locale, lead was detected at 0.25 ppm.

Table 7. Summary of the concentration of poly chlorinated biphenyls (ppb), mercury (ppm), and lead (ppm) in blue crab samples from various locations in the Chesapeake Bay Small Coastal Drainage. The concentrations of PCBs ranged from 2.66 - 25.94 ppb and had an average of 13.23 ppb. The concentrations of mercury ranged from 0.023 - 0.071 ppm with an average of 0.04 ppm. The concentrations of lead ranged from 0.050 - 0.075 ppm with an average of 0.06 ppm.

Location	Avg PCBs (ppb)	Avg Hg (ppm)	Avg Pb (ppm)
Lower Chesapeake Bay	9.64	0.057	0.050
Lower Peninsula Between James & York River	25.94	0.023	0.075
Middle Peninsula Between York River & Rappahannock River	2.66	0.023	0.050
Northern Neck Peninsula Between Rappahannock & Potomac River	6.92	0.071	0.050
Chesapeake Bay Eastern Shore	20.98	0.045	0.050
Average	13.23	0.04	0.06

While the average concentration of PCBs is less than the screening levels, two of the five locations did have a concentration of PCBS greater than the screening level. Due to this, PCBs may still pose a risk to human health. Since the average concentration of mercury is higher than the screening level, mercury may also pose a risk to human health. At four of the five locations, lead was under detection level. Therefore, a human health risk assessment will be conducted for PCBs, lead, and mercury.

7. Risk Assessment

Human health risk assessments were conducted for each contaminant that was of concern in each species. A non-carcinogenic risk assessment was conducted for lead and mercury; a carcinogenic risk assessment was conducted for PCBs. Blue crab data from Bluff Point, Virginia and from the Fish Tissue Monitoring Program were analyzed separately. The Fish Tissue Program did sample in locations surrounding Bluff Point, therefore analyzing the data separately allows for a comparison between the two data sets.

7.1 Bluff Point

Lead was detected in the composite backfin sample at a concentration of 0.138 mg/kg but was not detected in the composite hepatopancreas sample. The Environmental Protection Agency does not have a reference dose for lead, this is because a level of exposure that does not cause adverse effects has not been determined.[17] Since an acceptable levels of lead in fish tissue cannot be set, any lead detected in fish is a concern.[17]

7.2 Fish Tissue Monitoring Program

Lead was detected in the one of the five sampling locations within the Chesapeake Bay Small Coastal Drainage. At the other four locations, lead was detected below the detection limit of 0.1 ppm. These data were treated as half of the detection limit: 0.05 ppm. With this method of data treatment, the average concentration of lead was 0.055 ppm. Without the treatment, the average concentration of lead was 0.015 ppm. While any concentration of lead is a concern, the treatment of the data is what caused the concentration to be 0.055 ppm. Since the average concentration of lead is still below the detection limit of 0.1 ppm, a concentration of 0.055 ppm

would not have been able to be detected by the sampling method used. Due to this, a further investigation would need to be done to determine if lead poses a risk.

Mercury had an averaged concentration of 0.04 ppm, which is equivalent to 0.04 mg of mercury/ kg of blue crab tissue. Using standard EPA assumptions, the average daily dose of mercury from shellfish over a lifetime is equal to 4.52×10^{-6} mg/kg/day.

0.044 mg Hg	0.0175 kg fish	350 days	30 years	life	year	
kg blue crab	day	year	life	70 years	365 day	70 kg bodyweight

Figure 8. Calculations used to determine the average daily dose of mercury in blue crabs collected by the VaDEQ's Fish Tissue Monitoring program. The average daily dose is calculated by multiplying the concentration of contaminant by the consumption rate and then by the lifetime exposure. The ADD was calculated to be 4.52×10^{-6} mg/kg/day.

When the average daily dose is divided by the reference dose, it is equal to a hazard quotient of 0.452. Since the hazard quotient is less than 1, there is no risk of systemic toxicity from mercury in blue crabs.

$$\frac{4.52 \times 10^{-5}\,(\text{mg/kg-day})}{0.0001\,(\text{mg/kg-day})}$$

Figure 9. Calculations used to determine the hazard quotient. The hazard quotient is calculated by dividing the average daily dose by the reference dose.

Using standard EPA assumptions for standard exposure and toxicological values, fish/shellfish at or below a concentration of 0.40 mg/kg methyl mercury in edible muscle tissue would be considered to pose no significant health risk.[17] The EPA has estimated the average level of mercury exposure in commercial fish to be about 0.1 mg/kg/day, so 0.30 mg/kg methyl mercury in fish or shellfish is seen as acceptable.[17]

PCBs had an average concentration of 13.23 ppm, which is equivalent to 13.23 µg of PCBs/kg of edible blue crab tissue, or 0.0132 mg of PCBs/kg of edible blue crab tissue. Using EPA exposure and consumption rates, and body weight assumptions, the chronic daily intake is calculated to be 1.36×10^{-6} mg PCBs/kg body weight/day.

13.23 ug PCBs	0. 0.001 mg	0.0175 kg	30 years	life	year	
kg blue crab	ug	day	life	70 years	365 day	70 kg bodyweight

Figure 10. Calculations used to determine the chronic daily intake of PCB contamination from blue crab tissue. The final CDI was calculated to be 1.36×10^{-6}. This represents an risk of developing cancer higher than what the EPA believes is an acceptable level of risk.

When this is multiplied by the potency factor of 2.00 $(\text{mg PCBs/kg body weight/day})^{-1}$, the incremental lifetime risk is calculated to be 2.72 in 1,00,000 or 1 in 367,647. This represents a risk of developing cancer higher than the EPA's acceptable risk level of 1 in 1,000,000 but lower than the DEQ's acceptable risk level of 1 in 100,000.

8. Discussion and Conclusion

Typically, lead does not bioconcentrate in most fish, so it is considered somewhat unusual to see significant levels of lead in fish.[17] Being a neurotoxin that affects development, the biggest concern with lead is its effect on the development of a fetus or young children. Therefore, while lead may not be an immediate health risk, it is advisable for young children and pregnant mothers to avoid eating blue crabs (Table 8).

Table 8. Concentration of lead in blue crab and oysters. Blue crab samples collected in Bluff Point, Va. Oyster samples are from the VaDEQ's Fish Tissue Monitoring Program.

Fish Tissue	Concentration of Lead	Cancer Risk
Blue Crab	0.138 mg/kg	1 in 104,438

The samples collected from Bluff Point were analyzed as composite samples, which made analyzing a variety of different tissue types affordable. Unfortunately, composite samples also introduce some uncertainty. If only one blue crab in the entire sample has a high concentration of a contaminant, it can raise the entire average concentration of the sample to a level of concern. This especially introduces uncertainty for lead, since any detectable level of lead is of concern. A further investigation of lead, with a methodology that uses a lower method detection limit, needs to be completed in order to fully quantify if lead poses a risk.

Consuming blue crabs from the Chesapeake Bay presents an increased risk is greater than the Environmental Protection Agency's acceptable risk of 1 in 1,000,000, but is lower than the Virginia Department of Environmental Quality's acceptable risk of 1 in 100,000 or the (Table 10). Therefore, the standard used as an acceptable risk of cancer determines whether or not the increased risk of developing cancer is significant. This introduce a source of arbitrariness in concluding whether or not PCBs are causing an unacceptably high risk of developing cancer.

Cancer risks of are based on specific EPA assumptions. These assumptions include a default consumption rate of 17.5 grams of fish or shellfish per day, which is equivalent to 14.08 pounds of fish and shellfish per year or to 28 eight-ounce meals a year of locally caught fish and shellfish.[17] Consuming a greater amount of fish or shellfish per year would lead to a greater risk of developing cancer. The EPA also assumes that a person will eat this concentration of locally caught shellfish and fish for 30 years of a 70 year lifetime. This assumption takes into account that a person will not typically live in the same location for their entire life, however this is not true for many individuals. A person who spends a larger portion of their life in a community that consumes locally caught fish and shellfish would be a greater risk for developing cancer. Furthermore, the EPA assumes a standard body weight of 70 kg or 154.3 lbs. A person weighing less than this assumption would be at a greater risk for developing cancer.

Another assumption made by the EPA is that the entirety of fish and shellfish consumed have the same average PCB concentration as that of the blue crab, oysters, or striped bass. In order to compensate for this assumption, a risk assessment was done using the average concentration of PCBS in the three species. This risk assessment determined a risk of developing cancer of 1 in 69,414. This represents a risk of developing cancer higher than both the DEQ's acceptable risk level of 1 in 100,000 and the EPA's acceptable risk level of 1 in 1,000,000.

Polychlorinated biphenyl are man-made chemicals, therefore they are not found naturally in the environment. The stability of PCBs is what once caused them to be widely used in industrial and agricultural processes.[18] This poses a remediation problem because microorganisms typically do not have the ability to degrade compounds that are not found naturally in the environment.[18] Furthermore, the number of chlorines present has a large effect on the compounds persistence. Dr. An Li has been studying the persistence of PCBs and similar compounds in the Great

Lakes.[18] According to Li, in the 1970s, PCB production was high, as these compounds were released into the water, they accumulated in sediments.[18] Once the production of PCBs was halted, the equilibrium of PCBs in the environment shifted so that PCBs are now exiting the sediment to the water, where they can either redeposit in the sediment, accumulate in fish, or evaporate into the air.[18]

Li is exploring the sediment degradation process of PCBs in the Great Lakes ecosystem. She believes that microorganisms have developed the ability to break down natural and synthetic organohalogens in sediments.[18] Li wants to conduct a genomic analysis on these microorganisms, in the hopes that it will reveal which communities of microorganisms have the ability to break down halogenated compounds.[18] It is her hope that scientists will be able to engineer microbes to use in remediation efforts to clean up persistent compounds.[18] If this was indeed achieved, these microorganisms could be utilized to remediated PCB contamination in the Chesapeake Bay.

A diet that is a mix of local and store bought fish would likely have a lower average PCB concentration because store-bought fish much compile by state and federal safety regulations, while recreational caught fish and shellfish does not. Therefore, varying the source of fish and shellfish consumed would lead to a lower risk of developing cancer. This includes varying between top predators, which likely have a higher concentration of mercury due to bioaccumulation, and benthic species, which likely have a higher concentration of PCBs and lead, with other species of fish and shellfish.

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10. Appendix

This appendix includes the Chain of Custody form for the blue crab samples, collected from Bluff Point, Va., and is between Jessanna August and the REIC lab. The initial results from REIC are also included.

449360

CHAIN OF CUSTODY RECORD

REIC
Research Environmental & Industrial Consultants, Inc.
MAIN LABORATORY & CORPORATE HEADQUARTERS:
P.O. Box 286 • 225 Industrial Park Rd, Beaver, WV 25813
800-999-0105 • 304-255-2500 • www.reiclabs.com

Client: Jessanna August ; Caitlin Shipman PO #
Contact Person Jessanna August Phone (540) 209-1899
QUOTE # Fax: Email: augustjb@dukes.jmu.edu
Address 1177 L Devon Ln. City Harrisonburg State Va Zip 22801
Billing Address (if different)
City State Zip
Site ID & State Project ID Sampler

MID-OHIO VALLEY Service Center
101 17th Street
Ashland, KY 41101
606-393-5027

SHENANDOAH Service Center
1557 Commerce Rd., Ste 201
Verona, VA 24482
540-248-0183

ROANOKE Service Center
3029-C Peters Creek Rd
Roanoke, VA 24019
540-777-1276

MORGANTOWN Service Center
16 Commerce Drive
Westover, WV 26501
304-241-5861

SAMPLE LOG & ANALYSIS REQUEST

TURNAROUND TIME

- [X] NORMAL
- RUSH TURNAROUND*: [ ] 5 DAY [ ] 3 DAY [ ] 2 DAY [ ] 1 DAY

*Rush work needs prior laboratory approval and will incur additional charges

Preservative Codes:
0 None
1 Hydrochloric Acid
2 Nitric Acid
3 Sulfuric Acid
4 Sodium Thiosulfate
5 Sodium Hydroxide/ Sodium Arsenite
6 Sodium Hydroxide
7 Ascorbic Acid
8 Sodium Bisulfate/Methanol
9 Ammonium Chloride
10 _____ *
11 _____ *
* (Use blanks for preservatives not listed.)

ENTER PRESERVATIVE CODE

SAMPLE ID	No. & Type of Containers	Sampling Date/Time	Matrix	Sample Comp/Grab	ANALYSIS & METHOD REQUESTED: PC Bs testing	Mercury testing	Lead testing
BP - BC - BF	1 glass jar	10/17/14/10:08PM		comp	X	X	X
BP - BC - HP	1 glass jar	10/17/14/10:30PM		comp	*	*	*
BP - BC - CL	1 glass jar	10/17/14/10PM		comp	*	*	*
BP - BC - LG	1 glass jar	10/17/14/10:23PM		comp	*	*	*

COMMENTS:
* Please keep on hold. Contact client regarding payment options.

temp @ SSC = 0°C by TJ

All analytical requests are subject to REIC's Standard Terms and Conditions.

Temperature at arrival: 0.° °C ICED? Y ✓ N___

Containers provided by: [✓] REIC [ ] Client

1			2			
Relinquished by (signature) Annamm B August	Oct 22.14 Date/Time 11:30		Relinquished by (signature)	Date/Time	FAX RESULTS [ ]	EMAIL RESULTS [✓]
Received by (signature)	10-22-14 Date/Time 1130		Received by (signature)	Date/Time	SHIPMENT ✓ Hand Delivered ___ Courier ___ UPS ___ FEDEX ___ USPS ___ OTHER	

COC-NCR-011414

REIC

Improving the environment, one client at a time...

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16 Commerce Drive
Westover, WV 26501
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Monday, November 10, 2014

Ms. Jessanna August
Ms. Jessanna August
1177 DEVON LANEE
HARRISONBURG, VA 22801

TEL: (540) 209-1899
FAX:

RE:

Work Order #: 1410R58

Dear Ms. Jessanna August:

REI Consultants, Inc. received 4 sample(s) on 10/22/2014 for the analyses presented in the following report.

Sincerely,

Billy Shirley

REI Consultants, Inc. - Case Narrative

WO#: 1410R58

Date Reported: 11/10/2014

Client: Ms. Jessanna August

Project:

The analytical results presented in this report were produced using documented laboratory SOPs that incorporate appropriate quality control procedures as described in the applicable methods. Verification of required sample preservation (as required) is recorded on associated laboratory logs. Any deviation from compliance or method modification is identified within the body of this report by a qualifier footnote which is defined at the bottom of this page.

All sample results for solid samples are reported on an "as-received" wet weight basis unless otherwise noted.

Results reported for sums of individual parameters, such as TTHM and HAA5, may vary slightly from the sum of the individual parameter results, due to rounding of individual results, as required by EPA.

The test results in this report meet all NELAP (and/or VELAP) requirements for parameters except as noted in this report.

Please note if the sample collection time is not provided on the Chain of Custody, the default recording will be 0:00:00. This may cause some tests to be apparently analyzed out of hold.

All tests performed by REIC Service Centers are designated by an annotation on the test code. All other tests were performed by REIC's Main Laboratory in Beaver, WV.

DEFINITIONS:
MCL: Maximum Contaminant Level
MDL: Method Detection Limit; The lowest concentration of analyte that can be detected by the method in the applicable matrix.
Mg/Kg or mg/L: Units of part per million (PPM) - milligram per Kilogram (weight/weight) or milligram per Liter (weight/volume).
NA: Not Applicable
ND: Not Detected at the PQL or MDL
PQL: Practical Quantitation Limit; The lowest verified limit to which data is quantified without qualifications. Analyte concentrations below PQL are reported either as ND or as a number with a "J" qualifier.
Qual: Qualifier that applies to the analyte reported.
TIC: Tentatively Identified Compound, Estimated Concentration denoted by "J" qualifier.
Ug/Kg or ug/L: Units of part per billion (PPB) - microgram per kilogram (weight/weight) or microgram per liter (weight/volume).

QUALIFIERS:
X: Reported value exceeds required MCL
B: Analyte detected in the associated Method Blank at a concentration > 1/2 the PQL
E: Analyte concentration reported that exceeds the upper calibration standard. Greater uncertainty is associated with this result and data should be consider estimated.
H: Holding time for preparation or analysis has been exceeded.
J: Analyte concentration is reported, and is less than the PQL and greater than or equal to the MDL. The result reported is an estimate.
S: % REC (% recovery) exceeds control limits

CERTIFICATIONS:
Beaver, WV: WVDHHR 00412CM, WVDEP 060, VADCLS 00281, KYDEP 90039, TNDEQ TN02926, NCDWQ 466, PADEP 68-00839, VADCLS (VELAP) 460148
Bioassay (Beaver, WV): WVDEP 060, VADCLS(VELAP) 460148, PADEP 68-00839
Roanoke, VA: VADCLS(VELAP) 460150
Verona, VA: VADCLS(VELAP) 460151
Ashland, KY: KYDEP 00094, WV 389
Morgantown, WV: WVDHHR 003112M, WVDEP 387

REI Consultants, Inc. - Analytical Report

WO#: 1410R58

Date Reported: 11/10/2014

Client:	Ms. Jessanna August	**Collection Date:**	10/17/2014 10:08:00 AM
Project:		**Date Received:**	10/22/2014
Lab ID:	1410R58-01A	**Matrix:**	Animal Tissue
Client Sample ID:	BP - BC - BF	**Site ID:**	

Analysis	Result	MDL	PQL	MCL	Qual	Units	Date Analyzed	NELAP
TOTAL METALS by ICP-MS			**Method: SW6020A (1998)**				**Analyst: LF**	
Lead	0.138	0.025	0.125	NA		mg/Kg	10/30/2014 8:38 PM	
MERCURY, Total SW7417B			**Method: SW7471B (2/07)**				**Analyst: CR**	
Mercury	ND	0.020	0.100	NA		mg/Kg	10/29/2014 10:20 AM	PA/VA

Notes:

Matrix spike recovery did not meet REIC control criteria due to matrix interference.

PCBS			**Method: SW8082A (2/07)**			**Analyst: NC**
Aroclor 1016	ND	0.0115	0.0494	NA	mg/Kg	10/29/2014 4:48 PM
Aroclor 1221	ND	0.0136	0.0494	NA	mg/Kg	10/29/2014 4:48 PM
Aroclor 1232	ND	0.00671	0.0494	NA	mg/Kg	10/29/2014 4:48 PM
Aroclor 1242	ND	0.0144	0.0494	NA	mg/Kg	10/29/2014 4:48 PM
Aroclor 1248	ND	0.00415	0.0494	NA	mg/Kg	10/29/2014 4:48 PM
Aroclor 1254	ND	0.00395	0.0494	NA	mg/Kg	10/29/2014 4:48 PM
Aroclor 1260	ND	0.00330	0.0494	NA	mg/Kg	10/29/2014 4:48 PM
Surr: Tetrachloro-m-xylene	77.5	NA	30-170	NA	%REC	10/29/2014 4:48 PM

REI Consultants, Inc. - Analytical Report

WO#: 1410R58

Date Reported: 11/10/2014

Client:	Ms. Jessanna August	**Collection Date:**	10/17/2014 10:30:00 AM
Project:		**Date Received:**	10/22/2014
Lab ID:	1410R58-02A	**Matrix:**	Animal Tissue
Client Sample ID:	BP - BC - HP	**Site ID:**	

Analysis	Result	MDL	PQL	MCL	Qual	Units	Date Analyzed	NELAP
TOTAL METALS by ICP-MS			**Method: SW6020A (1998)**				**Analyst: LF**	
Lead	ND	0.025	0.125	NA		mg/Kg	11/7/2014 8:09 PM	
MERCURY, Total SW7417B			**Method: SW7471B (2/07)**				**Analyst: CR**	
Mercury	ND	0.020	0.100	NA		mg/Kg	11/7/2014 11:20 AM	PA/VA
PCBS			**Method: SW8082A (2/07)**				**Analyst: NC**	
Aroclor 1016	ND	0.00584	0.0250	NA	H	mg/Kg	11/7/2014 8:00 PM	
Aroclor 1221	ND	0.00690	0.0250	NA	H	mg/Kg	11/7/2014 8:00 PM	
Aroclor 1232	ND	0.00340	0.0250	NA	H	mg/Kg	11/7/2014 8:00 PM	
Aroclor 1242	ND	0.00730	0.0250	NA	H	mg/Kg	11/7/2014 8:00 PM	
Aroclor 1248	ND	0.00210	0.0250	NA	H	mg/Kg	11/7/2014 8:00 PM	
Aroclor 1254	ND	0.00200	0.0250	NA	H	mg/Kg	11/7/2014 8:00 PM	
Aroclor 1260	ND	0.00167	0.0250	NA	H	mg/Kg	11/7/2014 8:00 PM	
Surr: Tetrachloro-m-xylene	74.5	NA	30-170	NA	H	%REC	11/7/2014 8:00 PM	